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U. S. NAVAL AIR DEVELOPMENT CENTER
JOHNSVILLE, PENNSYLVANIA

Aviation Medical Acceleration Laboratory

NADC-MA-6205 2 July 1962

Effects of Positive Pressure Breathing on
Performance During Acceleration

Bureau of Medicine and Surgery
Task MR005.13-1004.1 Report No. 7

Bureau of Naval Weapons
WepTask No. RAE 13J 012/2021/R005 01 001
Problem Assignment No. J04AE13-7

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Prepared by: Randall M. Chambers
Randall M. Chambers, Ph.D.

Robert Kerr, B.S.

William S. Augerson, CAPTAIN, MC, USA*
NASA Space Task Group

Donald A. Morway
Donald A. Morway, B.S.

Approved by: F. K. Smith
F. K. Smith, CAPTAIN, MC, USN (Ret.)
Director
Aviation Medical Acceleration Laboratory

* Now at the Division Support Group, 326th Medical Company, 101st Airborne Division, Fort Campbell, Kentucky.

SUMMARY

The effects of positive pressure breathing of 100% oxygen were evaluated in terms of increasing man's ability to perform a complex psychomotor task during sustained accelerations of 6, 8, 10, and 12 transverse G, and in terms of visual brightness discrimination requirements during sustained accelerations of 1, 2, 3, 5, and 7 transverse G, and 1, 2, 3, and 5 positive G. In addition, subjective reports regarding comfort and performance were obtained during all acceleration conditions. The following tentative conclusions are suggested:

a. At 6, 8, and 10 G_x, no differences in ability to perform a complex three-dimensional psychomotor task were observed. However, at 12 G_x there were definite suggestions that performance under conditions of positive pressure breathing of 100% oxygen was superior to normal (atmospheric) breathing of 100% oxygen.

b. Subjectively, the pilots reported that positive pressure breathing of 100% oxygen was superior to the condition of normal breathing of 100% oxygen in terms of breathing ease and general comfort.

c. During transverse accelerations at 1, 2, 3, 5, and 7 G_x, significantly less lighting contrast was required at 5 G_x for the condition of positive pressure breathing of 100% oxygen as compared with breathing 100% oxygen without pressure or normal air.

d. During transverse acceleration, both positive pressure breathing of 100% oxygen, and normal breathing of 100% oxygen, precluded the necessity of an increase in brightness contrast which was necessary for normal air conditions.

e. During positive accelerations at 1, 2, 3, and 5 G_z, positive pressure breathing of 100% oxygen required significantly less lighting contrast at 3 G_z than did either normal breathing of 100% oxygen or breathing normal air.

f. Subjectively, all subjects reported that positive pressure breathing of 100% oxygen was superior to the condition of normal breathing of 100% oxygen in terms of breathing ease and general comfort during exposure to transverse accelerations of 5 and 7 G_x and to positive accelerations of 3 and 5 G_z.

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INTRODUCTION

As the human subject experiences transverse acceleration ($+G_x$) in the supine position, he finds it increasingly difficult to breathe. This difficulty increases as a function of both time and amplitude; consequently, if the exposure to transverse acceleration is prolonged in time or increased in amplitude, the subject will rapidly become fatigued (3, 6, 9). Substernal chest pain, sensations of pressure on the chest and anterior surface of the body, dyspnea, tearing of the eyes, and miscellaneous discomforts may accompany the breathing difficulty and fatigue (4, 7, 8, 11). The subject's tolerance to prolonged high transverse acceleration appears to be limited primarily by these symptoms (5, 6, 7, 10, 11, 12). Although these particular symptoms may be alleviated by repositioning the subject so that he receives positive acceleration ($+G_z$), other symptoms such as grayout and blackout provide physiological tolerance limits to positive acceleration which are smaller in amplitudes for shorter durations (6). Thus, the recommended position for placing man within a sustained high acceleration environment is transverse supine. In most spacecraft, it is required that the astronaut be capable not only of sustaining himself physiologically, but also that he be capable of maintaining reliable psychomotor performance on a variety of perceptual and motor tasks.

During recent years, there has been much research designed towards developing ways to extend man's ability to sustain himself physiologically during exposure to transverse acceleration. One of the more recent approaches has been that of providing the subject with positive pressure breathing of 100% oxygen. Whereas the possibility exists that this procedure may embarrass some physiological systems, there are reports in the scientific literature in which the physiological tolerance limits to high sustained transverse accelerations were extended in time and in general physiological comfort (1, 10). The most striking of these was reported by Watson and Cherniak (10), who investigated the effects of positive pressure breathing on the respiratory mechanics and physiological tolerance of centrifuge subjects at 4, 6, 8, and 10 transverse supine G. At 8 G_x, for example, expiratory reserve volume for subjects during conditions of positive pressure breathing of 100% oxygen increased 270% over the expiratory reserve volume of these same subjects when breathing 100% oxygen without positive pressure. When nine experienced subjects were exposed to endurance runs of 10 G_x under experimental conditions of positive pressure breathing of 100% oxygen and control conditions of normal (atmospheric) breathing of 100% oxygen, a 67% increase in endurance time was observed with positive pressure. The mean time for the positive pressure condition (3.18 minutes) was significantly higher ($p < .001$) than the mean for the control condition (1.88 minutes). Also, the subjects reported that breathing

was much easier with positive pressure. The physiological measures portrayed a picture of protection against the major physiological defects which would ordinarily be expected. This experimental study substantiated earlier work by Armstrong (1) who observed that eight subjects exposed to transverse acceleration reported an alleviation of the pain and breathing difficulty when positive pressure breathing was provided.

Considering the obvious implications of these findings for extending man's physiological limits, it is important to consider the possibility that positive pressure may also influence the ability of man to perform perceptual and motor tasks during high sustained transverse acceleration (3). There is an absence of any prior experimental research on the effects of positive pressure breathing of 100% oxygen on psychomotor performance during exposure to acceleration (3, 4, 6). Consequently, the primary purpose of this paper is to report the results of two experiments which assess the following; (a) the effects of positive pressure breathing on the ability of subjects to perform a complex psychomotor task during exposure to high sustained transverse accelerations, and (b) the effects of positive pressure breathing on the ability of subjects to perform a visual brightness discrimination task during exposure to both transverse (G_x) and positive (G_z) accelerations.

EXPERIMENT I. Effects of Positive Pressure Breathing on Psychomotor Performance During Exposure to Transverse Acceleration.

A. Experimental Method. The subjects in the first experiment were six pilots, five from Edwards Air Force Base and one from the U. S. Naval Air Development Center. The two-gimbaled gondola at the end of the 50-foot Human Centrifuge of the Aviation Medical Acceleration Laboratory (AMAL) was used to produce coordinated acceleration exposures. Figure 1 presents a view of this facility. The centrifuge was operated to produce transverse supine accelerations of 6, 8, 10, and 12 G_x. Each acceleration run consisted of a 12 1/2-second ramp up to peak G, a two-minute plateau at peak G, and a 12 1/2-second ramp down to the static condition. Each pilot was instrumented with EKG leads, a blood pressure sensing device, earphones, and a standard A13A pressure breathing oxygen mask which contained a respiration thermistor and a microphone. The subject was strapped into a Mercury contour couch with the standard Mercury restraining harness. The subject viewed a Mercury-type instrument panel and performed an orbital reentry control task by operating a three-axis Mercury-type right-hand control stick. Figure 2 shows a typical pilot installation and his equipment within the gondola of the centrifuge. The subject observed the attitude and rate indicators and performed the piloting task with his right-hand control stick while breathing 100% oxygen from the regulator located at his right-hand side. Respiration frequency was measured through a thermistor installed in

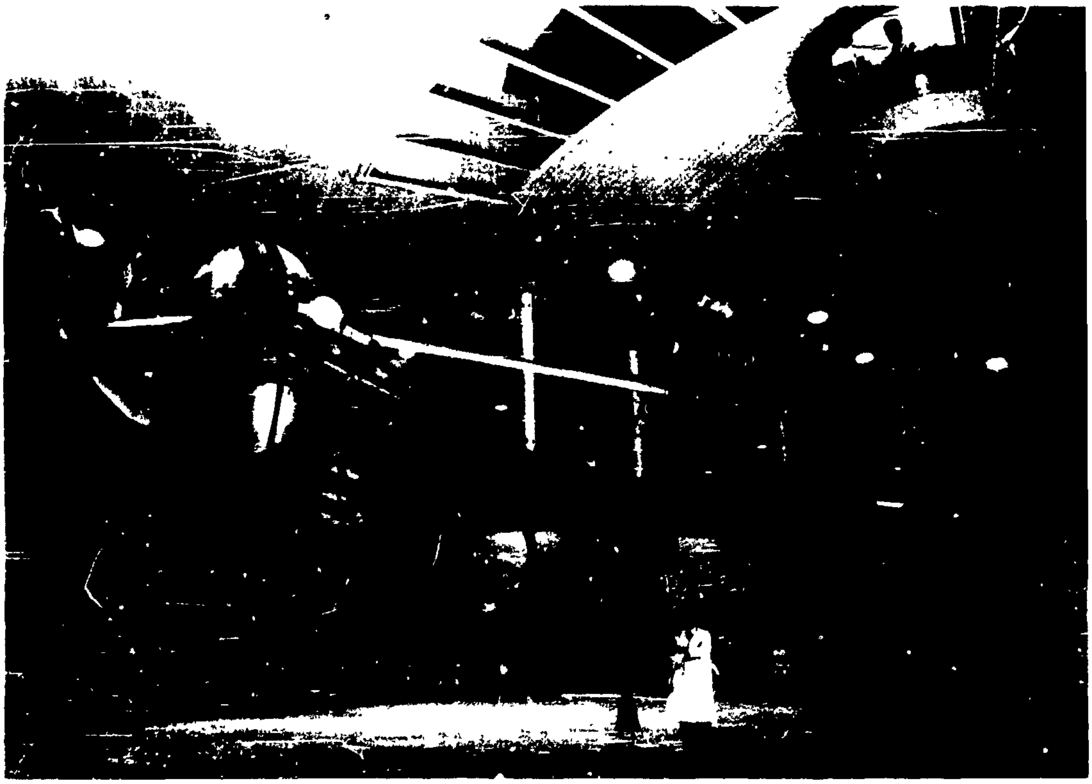


Figure 1. The two-gimbaled gondola at the end of the 50-foot arm of the AMAL Human Centrifuge, used for producing the acceleration environments in Experiments I and II.

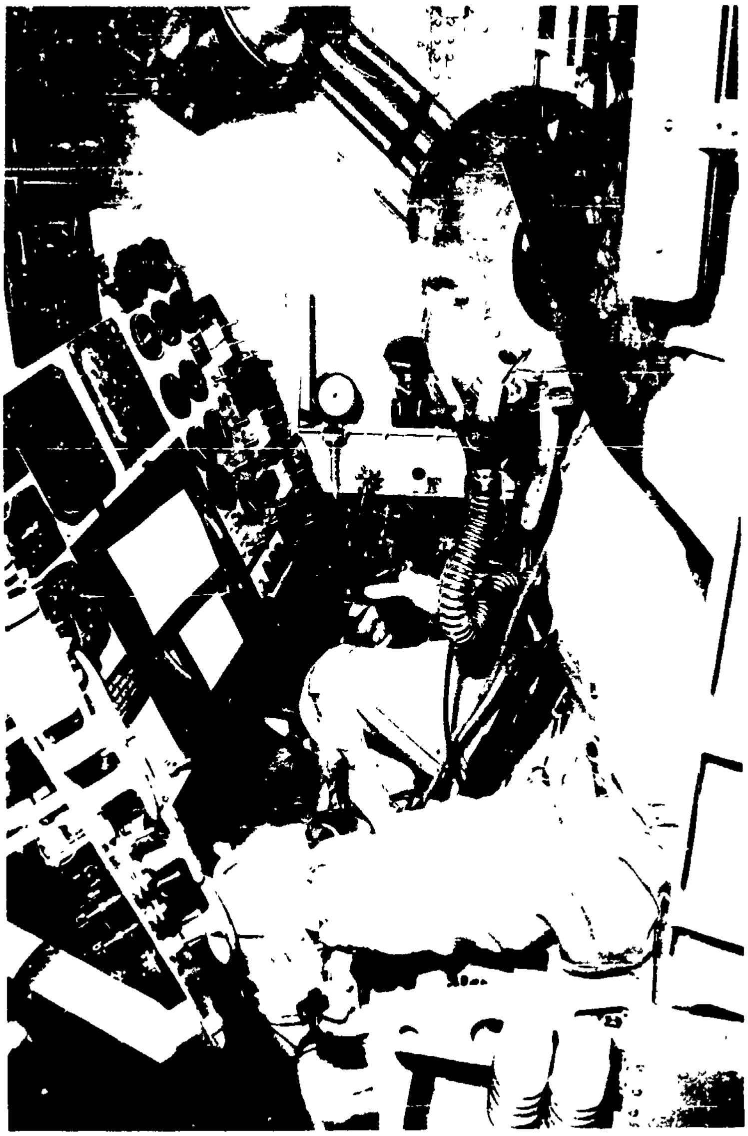
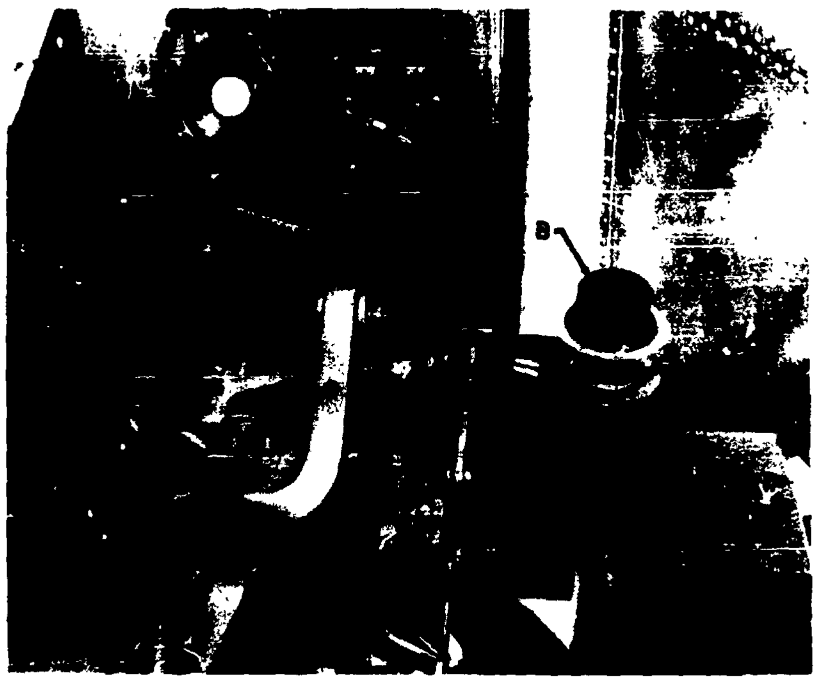


Figure 2. Pilot, mask, restraint system, three-axis side-arm controller, and instrument display panel used in Experiment I. The subject, restrained in a contour couch, observes the panel attitude and rate indicators, and performs the psychomotor task with the right hand controller while breathing 100% oxygen from the oxygen regulator at the right-hand side. Respiration frequency is measured through a thermistor installed in the exhalation valve of the oxygen mask.

the exhalation valve of the oxygen mask. A more detailed view of the A14 manually-controlled pressure breathing oxygen regulator and the three-axis Mercury-type control stick is shown in Figure 3. (The visual response button shown in this figure was used only in Experiment II.) The instrument display which the subject used in his performance task is shown in Figure 4. The attitude and rate indicators for pitch, roll, and yaw were programmed by a computer which simulated orbital reentry quantities, and it was the subject's task to maintain all indicators at specific predetermined positions by operating his three-axis side-arm controller. Piloting performance proficiency was recorded remotely by means of a small Donner computer system which continuously scored piloting errors in pitch, roll, and yaw. Figure 5 shows this equipment at the Performance Instrumentation Station. Mean integrated errors and variances for pitch, roll, and yaw were recorded on paper charts and magnetic tape for each half-minute interval during each two-minute run. (The piloting task was operated closed-loop, e.g., the pilot's control responses influenced the display which was in the centrifuge gondola via another remotely located computer system.) Pulse wave, blood pressure, respiration frequency and amplitude, and EKG were recorded at a Medical Monitoring Station located adjacent to the loading platform of the centrifuge. Piloting comments, subjective impressions, and answers to evaluation questions were recorded on an in-line audiograph before, during, and following each run.

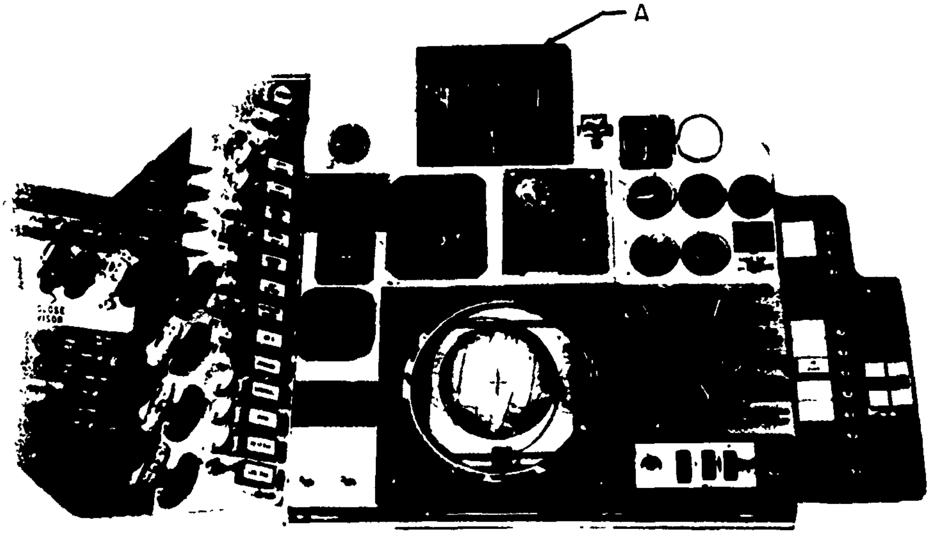
Prior to the beginning of any run, the subject was told the acceleration amplitude that he would experience. All centrifuge runs were scheduled for two minutes at peak G. However, since it was suspected that some subjects might not be able to physically endure the 10 G_x and 12 G_x runs for two minutes, an experimental design was selected which required each subject to receive the runs in random experimental-control pairs. The experimental condition for any given G level was positive pressure breathing of 100% oxygen, and the control condition for the same G was breathing 100% oxygen at normal (atmospheric) pressure. As any given run began, the subject was told the breathing conditions. For positive pressure breathing, he adjusted the pressure to his comfort until he reached a pressure ratio which was approximately 0.75 inches of water per G (1). These settings are shown in Table I. Then he performed his psychomotor control task. At the end of each run, the subject stopped performing the psychomotor control task, manually reduced the pressure to zero, and switched his breathing regulator to normal air. He was then given an opportunity to make comments and answer evaluative questions.

B. Results of Experiment I. Three types of data were obtained in Experiment I: (a) quantitative recordings of error, integrated error, and variance; in pitch, roll, and yaw attitude; (b) audiograph recordings of



Pressure Breathing Oxygen Regulator
A Mercury Type Control Handle
B. Oxygen Regulator
C Visual Response Button

Figure 3. Standard USAF A14 pressure breathing oxygen regulator, used in Experiments I and II. Pressures from 0 to 12.3 inches of water can be manually selected by the subject.



Mercury Type Control Panel
A. Attitude and Rate Indicators

Figure 4. Mercury-type control panel used in Experiment I. The attitude and rate indicators for pitch, roll, and yaw which the pilot used in performing his simulated orbital reentry maneuvers are shown in the upper part of the figure.

Figure 5. Performance Instrumentation Station, remotely located in a building near the centrifuge facility. At this station, piloting performance was recorded and analyzed in-line as each run proceeded, and integrated errors and variances in pitch, roll, and yaw were recorded.

TABLE I

OXYGEN REGULATOR SETTINGS

Setting Number	Pressure (In Inches of Water)
1	0.4
2	1.1
3	1.9
4	2.5
5	3.4
6	4.1
7	4.8
8	5.6
9	6.3
10	7.0
11	7.6
12	7.9
13	8.4
14	9.3
15	9.9
16	10.6
17	11.3
18	11.8
19	12.3

piloting opinion, comments, and responses to specific questions regarding breathing conditions, comfort, chest pain, vision, and endurance; and (c) physiological recordings of respiration, EKG, pulse wave, and blood pressure. The present paper is concerned primarily with the performance quantities and piloting opinion data.

The results for these two breathing conditions at 8, 10, and 12 G_x are summarized in Figures 6, 7, and 8. Figure 6 presents the mean integrated error in degrees for six subjects' pitch, roll, and yaw performance during four successive 30-second intervals under conditions of normal breathing of 100% oxygen and for pressure breathing of 100% oxygen during the 8 G_x acceleration exposures. The figure shows no significant differences in pitch, roll, and yaw error performance which may be attributed to the presence or absence of positive pressure breathing. Similar results are shown in Figure 7 for the 10 G_x series of centrifuge runs. However, during exposure to the 12 G_x series, some differences in performance were observed which may be attributed to the breathing conditions. These are presented in Figure 8. Of the four pilots who flew the 12 G_x centrifuge runs under both breathing conditions, only one was able to maintain psychomotor control performance for two minutes using normal breathing of 100% oxygen. Furthermore, this pilot's performance scores were all off scale (e.g., they exceeded the error score scale limits of 16 degrees) in pitch, roll, and yaw during the last half of the 12 G_x exposures. However, under conditions of positive pressure breathing of 100% oxygen, two of the pilots were able to maintain their psychomotor performance throughout the two-minute interval at 12 G_x, and their pitch, roll, and yaw scores during the last two 30-second intervals were as good as they had been at 8 G_x. These data suggest an advantage of the positive pressure breathing condition over the normal (atmospheric) breathing condition for performance at 12 G_x. Also, piloting opinion data obtained from all four pilots who attempted both conditions at 12 G_x indicated major improvement in comfort, endurance, and breathing ease as a result of positive pressure breathing.

An attempt was made to quantify the piloting opinion data for all acceleration levels and breathing conditions. At 6 G_x, 50% of the subjects who made experimental-control runs indicated that the positive pressure breathing of 100% oxygen was beneficial as compared with the normal breathing of 100% oxygen. At 8 G_x, 71% reported beneficial effects; at 10 G_x, 83% reported beneficial effects; and at 12 G_x, 100% reported beneficial effects. (One subject indicated that for the centrifuge runs, he preferred to use normal breathing rather than pressure breathing because of the mechanical and procedural difficulties which he encountered in using this particular positive pressure breathing equipment. He reported that there were beneficial effects resulting from positive pressure breathing, however, as compared with normal breathing.)

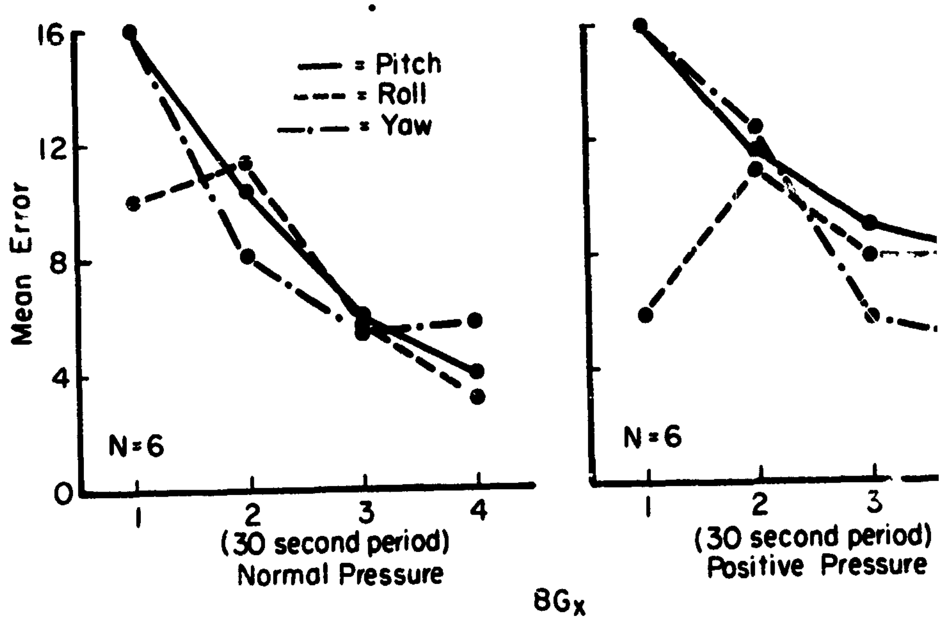


Figure 6. Mean degrees error for pilots in pitch, roll, and yaw
four successive 30-second intervals during exposure to 8 G_x unde
conditions of positive pressure breathing of 100% oxygen, and nor
breathing of 100% oxygen.

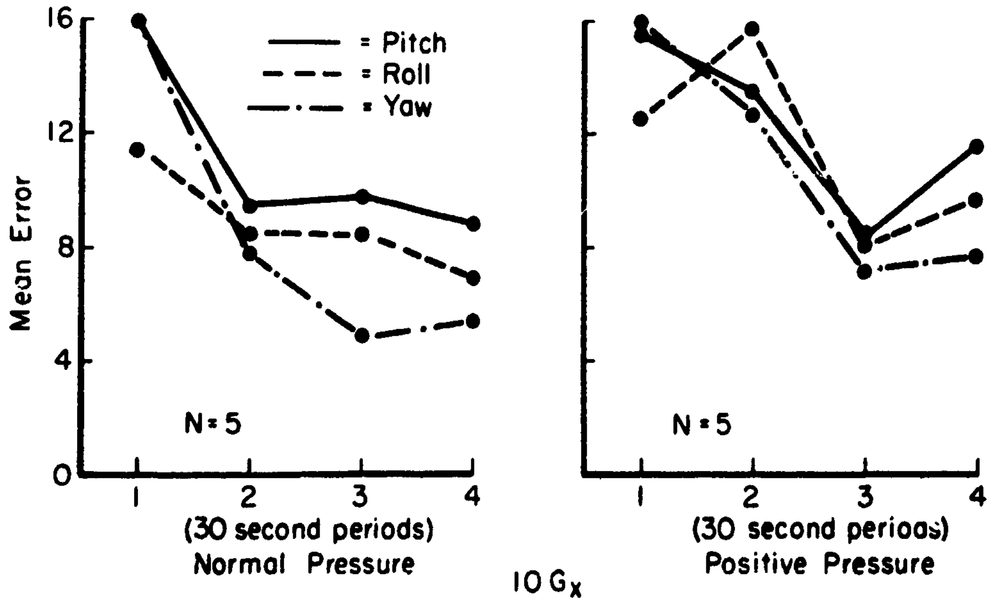


Figure 7. Mean degrees error for pilots in pitch, roll, and yaw for four successive 30-second intervals during exposure to 10 G_x under conditions of positive pressure breathing of 100% oxygen, and normal breathing of 100% oxygen.

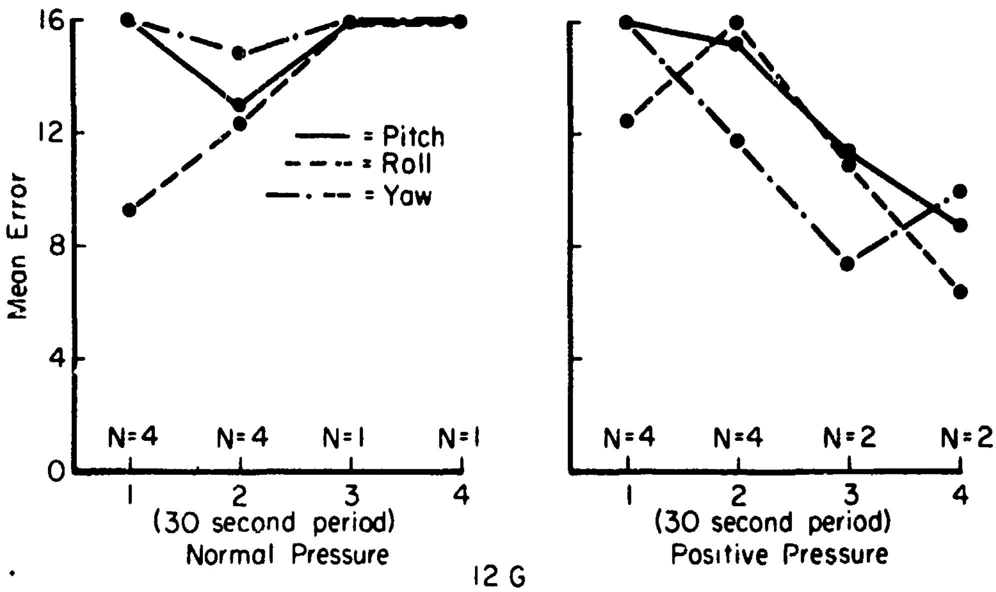


Figure 8. Mean degrees error for pilots in pitch, roll, and yaw for four successive 30-second intervals during exposure to 12 G_x under conditions of positive pressure breathing of 100% oxygen, and normal breathing of 100% oxygen.

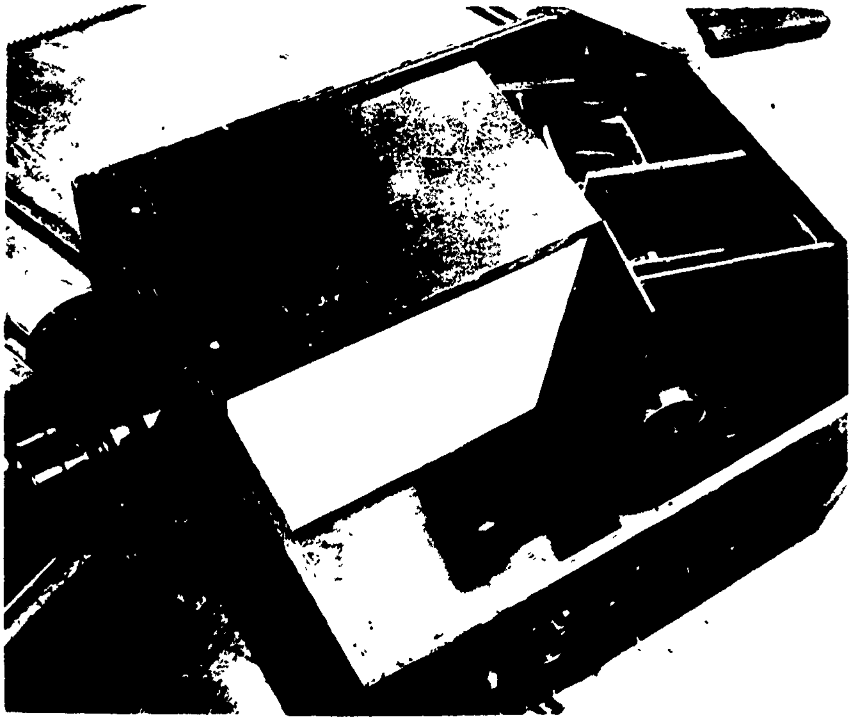
The data from blood pressure, respiration rate, pulse, and EKG recordings which were obtained before, during, and following centrifuge exposures showed such marked inter-subject variability that no significant differences in physiological quantities could be attributed to the breathing conditions, per se. Hence, no specific conclusions may be reported at this time, except that the breathing conditions did not have as great an effect on the physiological responses as did the acceleration conditions.

In summarizing the results of Experiment I, it may be stated that piloting performance at 6, 8, and 10 G_x did not differ according to the type of breathing provided. There was evidence, however, that at 12 G_x, performance in pitch, roll, and yaw was maintained better under conditions of positive pressure breathing of 100% oxygen than under conditions of normal breathing of 100% oxygen. At all G levels studied, there were subjective reports that physiological comfort, endurance, and ease of breathing were improved by the positive pressure condition. There were also subjective reports that vision was better and piloting concentration was improved under conditions of positive pressure breathing. These effects were most noticeable during the last half of the higher two-minute acceleration exposures.

EXPERIMENT II. Effects of Positive Pressure Breathing on Visual Brightness Discrimination.

A. Experimental Method. Experiment II investigated the effects of positive pressure breathing on visual brightness discrimination during exposure to lower levels of transverse acceleration and positive acceleration under conditions of positive pressure breathing of 100% oxygen, normal breathing of 100% oxygen, and breathing normal air. Subjects were five medical corpsmen with 20/20 uncorrected vision. All subjects had participated in a visual brightness discrimination experiment conducted in cooperation with the Cornell Aeronautical Laboratory (2). Each subject had had 20 transverse G runs and 16 positive G runs using the same visual brightness task and acceleration amplitude and duration conditions as those used in this experiment. Consequently, the subjects were highly trained and experienced in making this visual brightness discrimination under conditions of both positive and transverse acceleration.

A stimulus display generator (Figure 9) was mounted in the gondola of the centrifuge. This generator presented a circular test patch against a diffuse background. The display was viewed monocularly through an aperature 17 1/2 inches from the eye. The visual angles subtended by the circular test patch and background were 1° 29' and 8° 4' respectively. The background was generated by a matrix of eight 25 watt light bulbs behind



Stimulus Di' play Generator

Figure 9. Stimulus Display Generator used in Experiment II. A test patch was presented on a diffuse background via a slide projector. As the patch appeared and disappeared, the subjects made responses which were recorded on a digital voltmeter. Approximately 15 threshold determinations were made at peak G during each run.

two sheets of flashed opal. The test patch was projected onto the front sheet of flashed opal by a 500 watt slide projector. A view of the display is shown in Figure 10. Voltage to the projection bulb was controlled by a motor driven variac which altered the operating voltage at four volts per second. A neutral density filter was placed behind the viewing aperature to produce the desired background luminance of .03 foot lamberts. A response button was provided to the subject which was used to initiate the appearance or disappearance of the test patch. (Figure 3). After activation of the response button by the subject, the apparatus reversed the direction of the motor on the variac controlling test patch luminance. The time between the subject's response and reversal of direction ranged from 1.25 to 3.75 seconds, in a random manner. At the instant of the subject's response, the voltage to the projection bulb was recorded on a digital voltmeter located at the experimenter's station (Figure 11) which displayed this reading until the next response was made. Approximately 15 responses were made during peak G for each run. (A Spectra Brightness Spot Meter, Ultra Sensitive Model, was used to determine the target luminance values corresponding to the voltage readings.) Thus, with this apparatus, it was possible to continuously measure the subject's ascending and descending visual brightness thresholds. In addition to recording the subject's visual brightness threshold values at the experimenter's station, an in-line audiograph permitted the recording of subjective comments and other verbal reports before, during, and after each run.

The same USAF A14 manually-controlled pressure breathing oxygen regulator was used in Experiment I (Figure 3), and the same oxygen regulator settings were used as before (Table I). The installation of the stimulus display generator and other equipment within the centrifuge gondola is shown in Figure 12. Subjects wore standard flight suits for transverse G exposures, and for positive G exposures, standard USN cutaway type anti-G suits were also worn. During runs, the centrifuge chamber was darkened, and the initial target intensity of the stimulus was adjusted to a level below the minimum threshold for the 0.03 filter.

Both positive and transverse G were studied. A typical run consisted of a 12 1/2-second ramp up to peak G, a 90-second exposure at peak G, and a 12 1/2-second ramp down to the static condition. Positive pressure breathing of 100% oxygen was compared with normal breathing of 100% oxygen at 1, 2, 3, 5, and 7 G_x and at 1, 2, 3, and 5 G_z. Inasmuch as all subjects had already had extensive exposures to normal air breathing at these acceleration levels while performing the visual brightness discrimination task, these data were used as a base around which an experimental design was developed which enabled the comparison of all breathing conditions. The experimental design is summarized in Table II. All run

Figure 10. Subject viewing the stimulus in Experiment II.

Figure 11. Experimenter's station during Experiment II, showing area for recording visual brightness determinations and piloting comments.

Stimulus Display Generator Installed in Gondola
A. Stimulus Display Generator

Figure 12. Stimulus Display Generator installed in the gondola of the centrifuge.

TABLE II

EXPERIMENTAL DESIGN

S	R	G	B	S	R	G	B	S	R	G	B	S	R	G	B
$+G_x$															
2	1	3	O	3	1	1	P	5	1	3	O	6	1	7	P
	2	5	P		2	3	P		2	5	P		2	2	O
	3	1	O		3	7	P		3	1	O		3	5	O
	4	7	O		4	2	O		4	7	O		4	3	P
	5	2	P		5	5	O		5	2	P		5	1	P
	6	1	N		6	1	N		6	1	N		6	1	N
	7	2	O		7	5	P		7	2	O		7	1	O
	8	7	P		8	2	P		8	7	P		8	3	O
	9	1	P		9	7	O		9	1	P		9	5	P
	10	5	O		10	3	O		10	5	O		10	2	P
	11	3	P		11	1	O		11	3	P		11	7	O
$+G_z$															
1	1	3	P	3	1	2	P	5	1	2	P	6	1	3	P
	2	1	P		2	3	O		2	3	P		2	1	P
	3	5	O		3	1	O		3	5	O		3	5	O
	4	2	O		4	5	P		4	1	O		4	2	O
	5	1	N		5	1	N		5	1	N		5	1	N
	6	2	P		6	5	O		6	1	P		6	2	P
	7	5	P		7	1	P		7	5	P		7	5	P
	8	1	O		8	3	P		8	3	O		8	1	O
	9	3	O		9	2	O		9	2	O		9	3	O

S = Subject
R = Run number
G = Acceleration
B = Breathing mode (O = 100% oxygen, P = 100% oxygen plus pressure, N = normal air)

conditions were provided to all subjects. Immediately prior to any given run, the subject was told the level of G and instructed concerning his breathing mode. At this time, the subject selected, via the manually-controlled oxygen regulator, either normal air or 100% oxygen and the proper amount of pressure to be received. This determination was based on an increase of 0.75 inches of water pressure per G, as was used in Experiment I. The brightness discrimination task was started, the subject started responding, and the centrifuge started to turn. The subject continued responding as the stimulus appeared and disappeared until the end of the run, at which time he was instructed to stop responding, reduce pressure to zero, and return to normal air. During each run, response data and subjective comments were recorded, and medical data were monitored. Between runs, the subjects were interrogated concerning their impressions of the run and breathing conditions, their physical well-being and comfort, and their performance.

B. Results of Experiment II. Two types of data were obtained from Experiment II: (a) quantitative readings of the amount of illumination required by the subjects to maintain vision of the stimulus continuously before, during, and after peak G exposures, and (b) audiograph recordings of the subjective opinion and voice responses before, during, and following acceleration exposures.

Table III summarizes some of the results, showing the effects of positive pressure breathing on visual brightness discrimination during transverse accelerations of 1, 5, and 7 G_x. The table shows that at 1 G_x, there were no statistical differences among the three conditions, positive pressure breathing of 100% oxygen, normal breathing of 100% oxygen, and normal breathing of normal air. However, at the 5 G_x level, highly significant differences are shown among all three breathing conditions. Discrimination thresholds were significantly lower under conditions of 100% oxygen than under normal air conditions ($p < .01$). The discrimination thresholds obtained under the two 100% oxygen conditions did not differ significantly at either the 5 G_x or the 7 G_x level.

The results of the analysis of some of the data on positive pressure breathing during exposure to 1, 3, and 5 G_z are shown in Table IV. At 1 G_z no significant differences occurred among the various breathing conditions. However, at 3 G_z highly significant ($p < .01$) differences were found between the visual discrimination thresholds for all three breathing conditions. At 5 G_z there were highly significant differences between the 100% oxygen with pressure condition as compared with the normal air condition. The other differences were in the same direction as for 3 G_z, but they were not statistically significant.

TABLE III

COMPARISON OF BREATHING MODES FOR TRANSVERSE ACCELERATION

	$+1G_x$			$+5G_x$			$+7G_x$		
	Normal Air vs 100% Oxygen	Normal Air vs 100% Oxygen Plus Pressure	100% Oxygen vs 100% Oxygen Plus Pressure	Normal Air vs 100% Oxygen	Normal Air vs 100% Oxygen Plus Pressure	100% Oxygen vs 100% Oxygen Plus Pressure	Normal Air vs 100% Oxygen	Normal Air vs 100% Oxygen Plus Pressure	100% Oxygen vs 100% Oxygen Plus Pressure
$\bar{X}_1$	2.41	2.41	2.40	3.47	3.47	2.39	3.32	3.32	2.59
$\bar{X}_2$	2.40	2.64	2.64	2.39	2.26	2.26	2.59	2.52	2.52
$\bar{D}$	0.01	0.23	0.24	1.08	1.21	0.13	0.73	0.80	0.07
$S_{\bar{D}}$	0.16	0.28	0.23	0.37	0.33	0.16	0.43	0.41	0.30
t	.062	.821	1.04	2.91	3.66	.812	1.69	1.94	.233
df	30	30	30	30	30	30	22	22	22
P	$>.5$	$<.5 >.1$	$<.5 >.1$	$<.01$	$<.01$	$<.5 >.1$	$<.5 >.1$	$<.1 >.05$	$>.5$

TABLE IV

COMPARISON OF BREATHING MODES FOR POSITIVE ACCELERATION

	$+1G_z$			$+3G_z$			$+5G_z$		
	Normal Air vs 100% Oxygen	Normal Air vs 100% Oxygen Plus Pressure	100% Oxygen vs 100% Oxygen Plus Pressure	Normal Air vs 100% Oxygen	Normal Air vs 100% Oxygen Plus Pressure	100% Oxygen vs 100% Oxygen Plus Pressure	Normal Air vs 100% Oxygen	Normal Air vs 100% Oxygen Plus Pressure	100% Oxygen vs 100% Oxygen Plus Pressure
$\bar{X}_1$	2.55	2.55	2.67	3.73	3.73	3.02	4.97	5.38	4.62
$\bar{X}_2$	2.67	2.63	2.63	3.02	2.42	2.42	4.62	3.83	4 26
$\bar{D}$	0.12	0.08	0.04	0.71	1.31	0.60	0.35	1.55	0.36
$S_{\bar{D}}$	0.13	0.14	0.11	0.12	0.17	0.18	0.41	0.58	0.51
t	.923	.571	.363	5.91	7.70	3.33	.853	2.65	.705
df	30	30	30	30	30	30	14	28	14
P	$< .5 > .1$	$> .5$	$> .5$	$< .01$	$< .01$	$< .01$	$< .5 > .1$	$< .02 > .01$	$< .5 > .1$

Figure 13 has been prepared to show the effects of repeated trials under each of the three breathing conditions during the transverse acceleration runs. The mean foot lamberts required for maintaining vision of the test patch did not change consistently during any of these conditions. Similarly, for the positive acceleration exposures, there were no consistent trial effects, as shown in Figure 14.

In order to compare the visual brightness contrast requirements at all transverse acceleration levels for all breathing conditions, Figure 15 is presented. The figure shows that the oxygen and also the oxygen plus positive pressure breathing enabled the subjects to maintain their vision at a constant level. However, under conditions of normal breathing of air, the mean amount of required visual brightness contrast increased as G increased.

A similar figure is presented for positive acceleration. These data are presented in Figure 16. Here, normal air breathing required more contrast than did the other two conditions. However, beginning with 3 positive G, the condition of positive pressure breathing of 100% oxygen required less contrast than did either of the other two breathing conditions. *

In order to quantify the subjective impressions, comments, and answers to questions provided by the subjects in this experiment, a content analysis of their reports was performed. The results shown in terms of subjective beneficial effects of the positive pressure breathing of oxygen as compared with the other two breathing conditions, are shown in Figure 17. The figure shows the results for both positive and for transverse acceleration on the same coordinates. For both acceleration vectors, the percentage of subjects reporting beneficial effects started at zero and ended at 100%, thus suggesting subjective improvements as the acceleration magnitudes increased.

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* The Cornell Aeronautical Laboratory, Inc., conducted a detailed four-way analysis of variance in which the pressure breathing data was included with scores which these same subjects made under conditions of breathing normal air and breathing 100% oxygen normally. In addition to breathing method, other variables (position, acceleration, and subjects) were also included in the analysis. They obtained a highly significant F ratio of 53.66, indicating differences according to the method of breathing. However, the portion of the data concerning pressure breathing must be regarded as tentative and preliminary, because this analysis confounds the data from two separate experiments with the variable of pressure breathing.

DISCUSSION OF RESULTS

These results appear to suggest that positive pressure breathing of 100% oxygen extends the perceptual and motor performance capabilities of man under conditions of prolonged high transverse acceleration. Control data in this experiment agree with data reported by other investigators in which normal breathing conditions of oxygen or normal air were used (9, 3, 4, 6). Many of the physiological symptoms of high sustained transverse accelerations noted by previous investigators (6, 7, 5, 12, 1, 11) appear to have been somewhat alleviated by positive pressure breathing. Our data appear to be in general agreement with the work of Armstrong (1) and Watson and Cherniak (10), although the emphasis in our experiments was on perceptual and motor performance. Although more research is needed on a larger sample of subjects, our preliminary findings on the effects of positive pressure breathing on psychomotor performance and visual brightness thresholds are in general agreement with theoretical predictions.

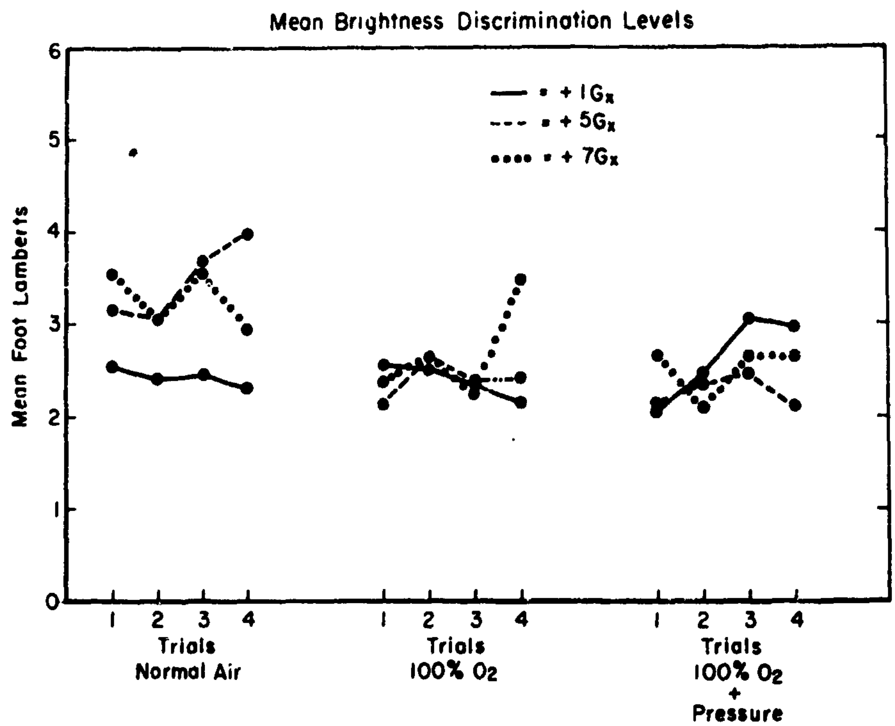

Figure 13. Comparison of visual brightness discrimination data obtained from subjects during repeated exposures to G_x accclerations under three breathing conditions.

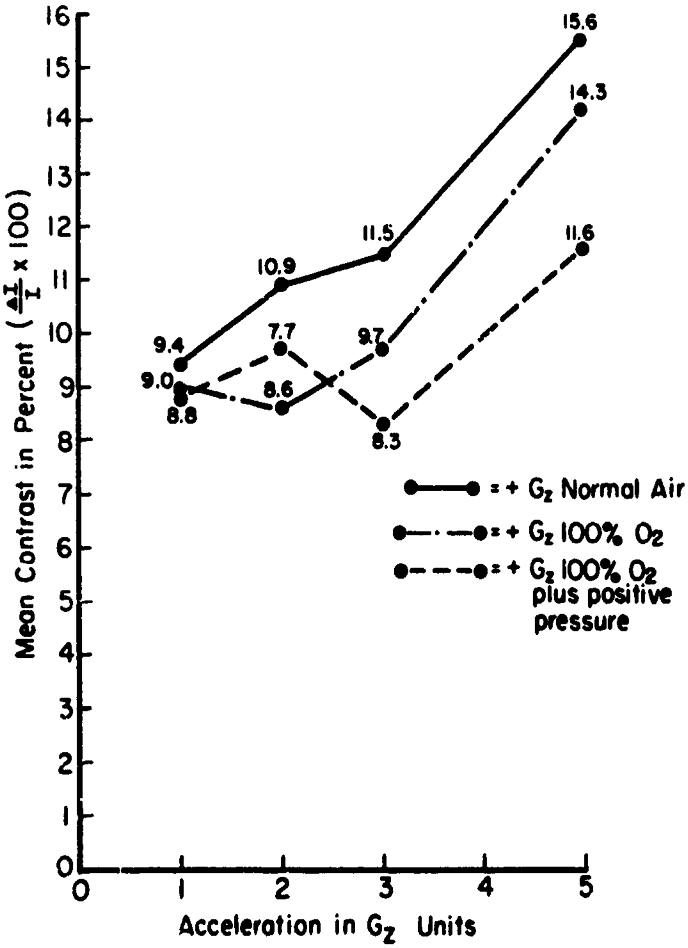

Figure 14. Comparison of visual brightness discrimination data obtained from subjects during exposure to G_z accelerations under three breathing conditions.

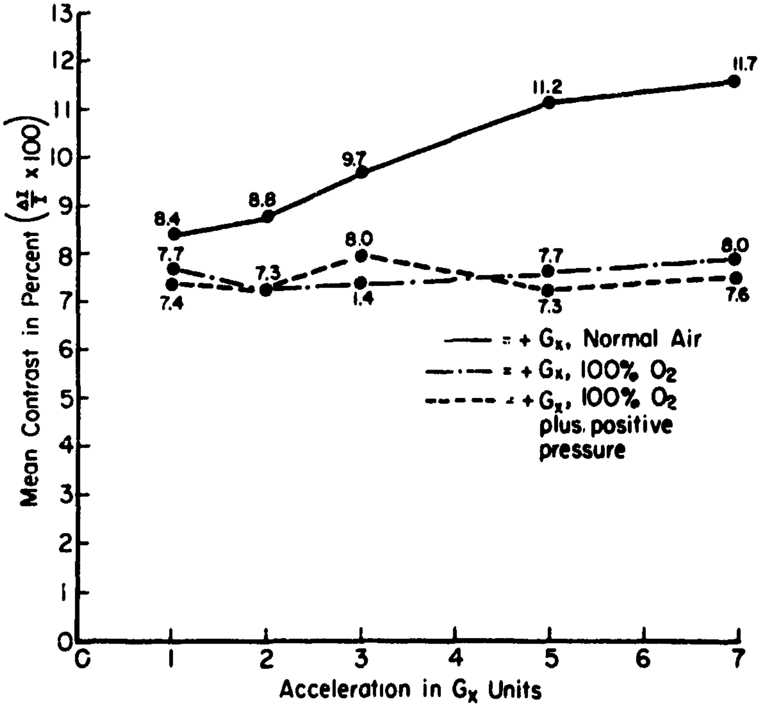

Figure 15. Mean brightness discrimination levels for 1, 5, and 7 G_x under conditions of normal air, 100% oxygen, and 100% oxygen plus positive pressure.

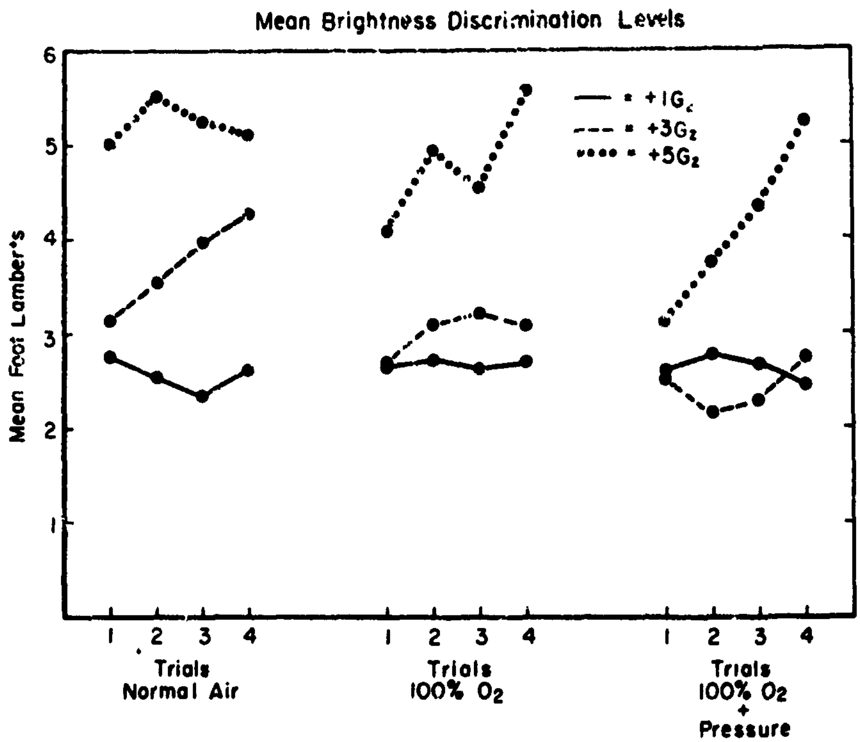

Figure 16. Brightness discrimination levels for 1, 3, and 5 G_z for each of three breathing conditions.

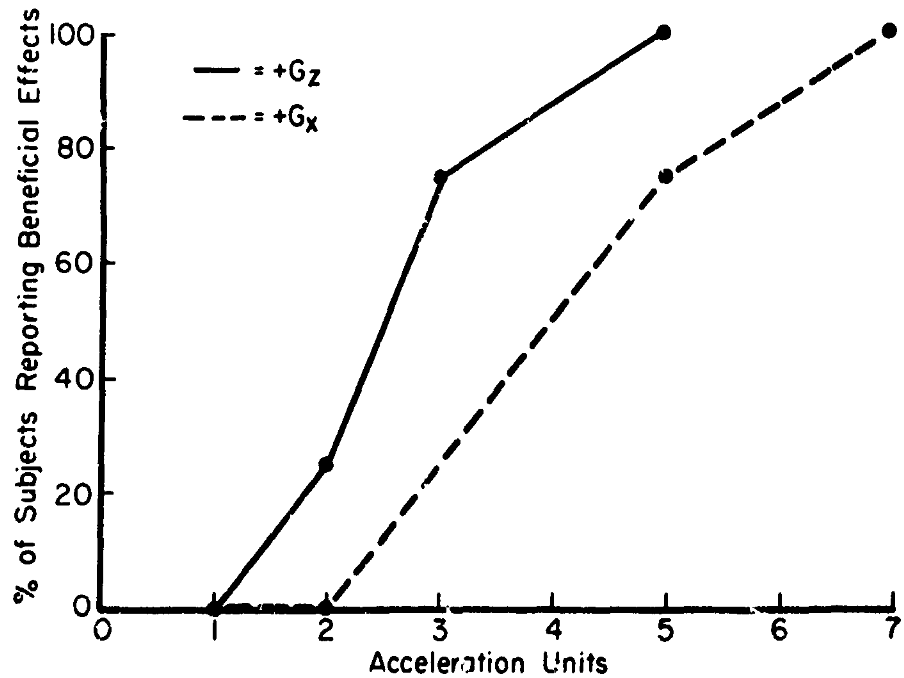

Figure 17. Percent of subjects reporting beneficial effects of positive pressure breathing of 100% oxygen as compared with normal breathing of 100% oxygen and normal air at different levels of positive and transverse acceleration.

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2. Task MR005.13-1004.1
WepTask No. RAE 13J 012/2021/R005 01 001
Problem Assignment No. J04AE13-7

Effects of Positive Pressure Breathing on Performance During Acceleration: by Randall M. Chambers, Ph.D., Robert Kerr, B.S., William S. Augerson, CAPT, MC, USA, and Donald A Morway, B.S., 2 July 1962, 32 pp.

The effects of positive pressure breathing of 100% oxygen were evaluated in terms of increasing man's ability to perform a complex psychomotor task during sustained accelerations of 6, 8, 10, and 12 transverse G, and in terms of visual brightness discrimination requirements during sustained accelerations of 1, 2, 3, 5, and 7 transverse G and 1, 2, 3, and 5 positive G. In addition, subjective reports regarding comfort and performance were obtained during all acceleration conditions. The following tentative conclusions are suggested: (a) At 6, 8, and 10 G_x, no differences in ability to perform a complex three-dimensional psychomotor task were observed. However, at 12 G_x there were definite suggestions that performance under conditions of positive pressure breathing of 100% oxygen was superior to normal (atmospheric) breathing of 100% oxygen. (b) Subjectively, the pilots reported that positive pressure breathing of 100% oxygen was superior to the condition of normal breathing of 100% oxygen in terms of breathing ease and general comfort. (c) During

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